Appendix E
Water Characterization Study

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FINAL
Water Characterization Study
Schofield Generating Station Project
USAG-HI Schofield, Oahu, HI

Submitted by:

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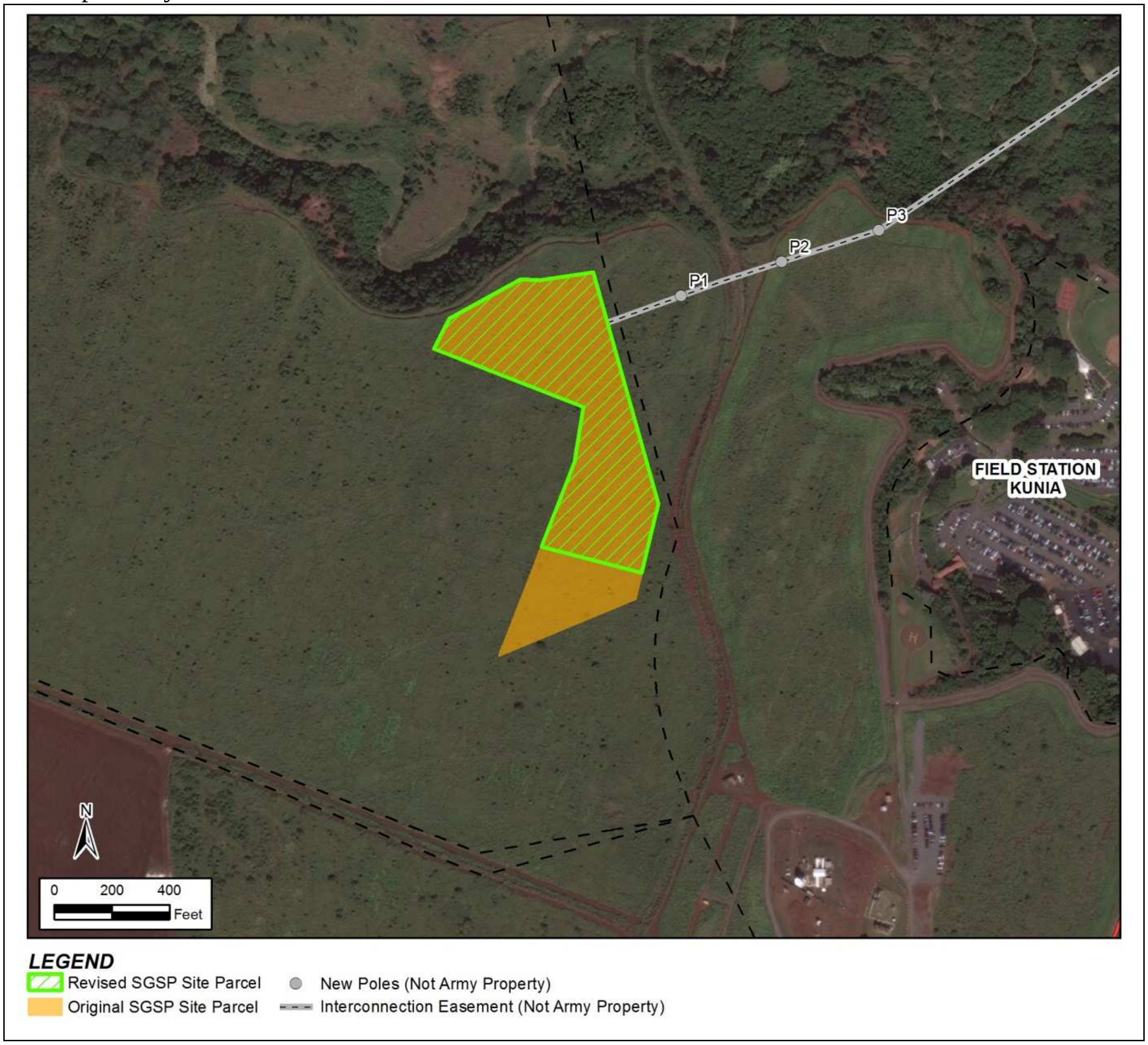
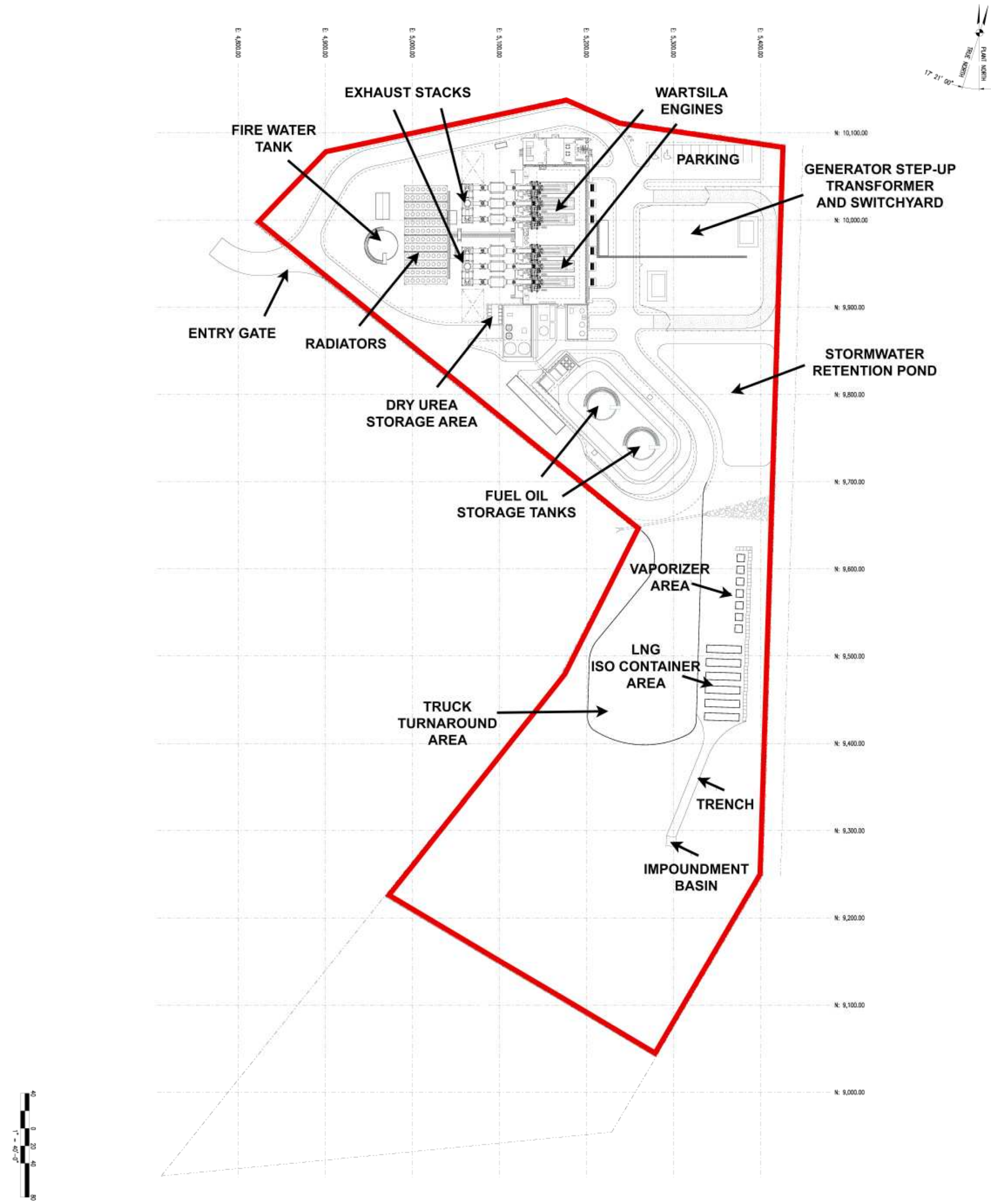
Errata

Prepared on August 18, 2014

After completing the Water Characterization Study, the Army and Hawaiian Electric reduced the size of the parcel on which the generating station will be located and revised the conceptual site layout to accommodate infrastructure associated with use of containerized liquefied natural gas if and when it becomes an available fuel source for the project. The Schofield Generating Station parcel was reduced from 10.3 acres to 8.13 acres. The first map below shows the reduced parcel indicated by hatch marks and the second map shows the revised site conceptual plan. Please note that the figures and discussions within the Water Characterization Study are based on the larger 10.3 parcel and initial conceptual design, and therefore do not match the parcel size and site design discussed in the EIS. However, the reduction in parcel size and revised site layout does not affect the recommendations made in the Water Characterization Study regarding storm water management. In fact, recommendations in the Water Characterization Study were taken into account during the redesign of the site conceptual layout.




EXHAUST STACKS
WARTSILA ENGINES
FIRE WATER TANK
PARKING
GENERATOR STEP-UP TRANSFORMER AND SWITCHYARD
ENTRY GATE
RADIATORS
STORMWATER RETENTION POND
DRY UREA STORAGE AREA
FUEL OIL STORAGE TANKS
VAPORIZER AREA
LNG ISO CONTAINER AREA
TRUCK TURNAROUND AREA
TRENCH
IMPOUNDMENT BASIN

EXECUTIVE SUMMARY

The National Environmental Policy Act (NEPA) requires federal agencies to account for environmental impacts and identify mitigation options by submitting environmental impact statements (EIS) for federal projects. In 2007, Congress passed the Energy Independence and Security Act (EISA), and Section 438 of that legislation establishes strict stormwater runoff requirements for federal development and redevelopment projects. Additional Army policies enacted in 2010 encourage the use of low impact development (LID) to manage stormwater on federal property. The 2010 Army policies also require a potable water use reduction of 30 percent and suggest rainwater harvesting as an option. Further, local regulations require developments to comply with flood control criteria specified in the City and County of Honolulu Rules Relating to Storm Drainage Standards (2000).

The purpose of this study is to:

1) identify cost effective solutions (mitigation measures) to meet compliance with federal and local regulations for the U.S. Army Garrison Hawaii and Hawaii Electric Company's proposed Schofield Generating Station (SGS) near Schofield Barracks on the Hawaiian island of O'ahu, and
2) document these mitigation measures in support of the NEPA EIS for the SGS project.

This characterization study analyzes two options to mitigate post-development runoff for EISA compliance; Option 1 requires retaining the 95th percentile rainfall event on-site (by means of infiltration, evapotranspiration, or reuse), and Option 2 requires maintenance or restoration of predevelopment hydrology on the basis of site-specific conditions through the use of continuous simulation modeling techniques, published data, studies, or other established tools. Modeling results identified Option 1 as the cost-effective compliance solution. When compared to Option 2, Option 1 identified a 34 percent smaller facility that would be required to retain the runoff generated by the 1.8 inch, 95th percentile event.

Once EISA Option 1 was identified as the more cost-effective compliance solution, two alternatives were proposed to select a design that is compliant with EISA Option 1, provides cost-effective stormwater management, and supports the Army's goal for a sustainable future. Alternative 1 proposed the conceptual plan's detention basin as an infiltration basin best management practice (BMP). Alternative 2 included LID implementation of distributed bioretention and cistern BMPs throughout the site. Based on optimization modeling results, Alternative 1 was projected to cost 18% less than Alternative 2, and was selected as the optimal design.

In addition to the EISA requirements, Honolulu City and County Storm Drain Standards state that additional storage would be needed to retain and infiltrate the 10-year design storm excess runoff from post-development conditions. To accommodate this, the proposed Option 1 BMP volume would need to be expanded by 0.071 ac-ft.

Army LID policy requires that rainwater harvesting be considered for new federal site designs. A continuous simulation model was used to guide selection of an optimum cistern size based on a projected daily municipal water use of 500 gallons. A 30-year return on investment (ROI) analysis was also performed to determine the cost-effectiveness of a rainwater harvesting system. Results predicted that rainwater harvesting could offset 71% of long-term potable water demand at SGS by implementing an 8,000-gallon cistern with a backup water supply. The 30-year ROI analysis predicted an 11-year payback period for the recommended system.

Final recommendations for stormwater management at the proposed SGS include meeting EISA compliance and flood control requirements using an infiltration basin BMP. Rainwater harvesting implementation will help reduce potable water use and promote a sustainable future for the Army. These designs are recommended as a cost-effective and sustainable solution to mitigate for potential environmental impacts due to the development of SGS at U.S. Army Garrison-Hawaii, Schofield.

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1 INTRODUCTION

1.1 PURPOSE

The United States Army (Army) Schofield Barracks is located on the island of O’ahu, Hawaii, in Honolulu County. The Army must increase their renewable energy sources to adhere to Federal energy statutes and mandates and ensure 100% energy security to the Schofield Barracks, Wheeler Army Airfield, and Kunia Station. To meet these requirements, the Army is proposing to lease of 10.3 acres of undeveloped land and a related 2.5-acre interconnection easement on Schofield Barracks to Hawaiian Electric, for Hawaiian Electric’s construction, ownership, operation, and maintenance of a 50 MW capacity biofuel-capable power generation plant and 46-kilovolt subtransmission line required to connect the Schofield Generating Station to the Hawaiian Electric grid. If implemented, the SGSP would be a source of renewable power that would provide energy security for the installations if loss of service occurs.

The SGSP would benefit Hawaiian Electric and the residents of O‘ahu. It would add 50 MW of utility-owned, dispatchable capacity to the O‘ahu grid; provide a quick-starting, high-ramp rate facility to help maintain grid stability and compensate for increasing network penetration by variable sources of power generation, such as wind and solar; provide a power generation facility at a higher elevation and away from coastlines, which contributes to grid reliability and continuity of operation if a natural disaster occurs; provide a physically secure power generation facility on a military installation, contributing to grid continuity of operation in cases of a man-made threat; and make progress towards the State Renewable Portfolio Standards.

The project is proposed to be constructed on an undeveloped site (formerly agricultural land), which, if left unmitigated, could have adverse impacts on the environment.

The United States National Environmental Policy Act (NEPA) introduced national environmental considerations and implementations for the federal government. NEPA Title I declared federal agencies to “use all practicable means to create and maintain conditions under which man and nature can exist in productive harmony” (NEPA citation). NEPA requires federal agencies to prepare environmental impact statements (EIS) to analyze potentially significant environmental effects and alternatives for proposed federal projects and decisions. This report addresses stormwater management for the SGSP EIS; in particular, the pre- and post-development hydrology was characterized and environmental solutions were identified to comply with relevant regulations.

The purpose of this study is to:

1) identify cost effective solutions (mitigation measures) to meet compliance with federal and local regulations for the proposed project and
2) document these mitigation measures in support of the NEPA EIS for the proposed project.

1.2 REGULATORY BACKGROUND

The following section outlines the pertinent federal and local regulations and policies governing stormwater management at the proposed project site.

1.2.1 EISA REGULATIONS

Congress enacted the Energy Independence and Security Act (EISA) in December 2007; Section 438 of that legislation establishes strict stormwater runoff requirements for federal development and redevelopment projects. The legislation reads as follows:

> The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow. (EISA 2007)

Section 438 is intended to address the inadequacies of common approaches to managing stormwater and promote practices that maintain or restore predevelopment site hydrology. Although Congress did not prescribe specific strategies to comply with Section 438, it can be inferred that one of the goals of the act is to promote the use of sustainable stormwater management approaches, designs, and practices that better protect receiving water quality and better address volume control (USEPA 2009). LID is the preferred approach that can be used to meet the criteria of Section 438. To assist federal agencies with compliance, EPA developed Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act. EPA's technical guidance document describes two options for demonstrating compliance with EISA Section 438 requirements, each of which is intended to achieve the outcome of maintaining or restoring predevelopment hydrology. Option 1 is to retain the 95th percentile rainfall event on-site, and Option 2 is to determine predevelopment hydrology on the basis of site-specific conditions through the use of continuous simulation modeling techniques, published data, studies, or other established tools to determine the volume of water to be managed and retained on-site. (USEPA 2009)

1.2.2 ARMY LID POLICIES

In a 2010 memorandum, the Army instated requirements for managing stormwater with LID. This memorandum was distributed as a follow-up to Section 438 of EISA, Department of Defense (DoD) Stormwater Requirements for EISA, and a June 2010 sustainable design and development policy memorandum update. The Army addresses the need to take a more sustainable, innovative approach, like LID, to manage the stormwater runoff from Army-owned land, regardless of size and type of construction projects. The LID guidelines were instated in 2011 for all "sustainment, restoration, and modernization (SRM) funded projects", and all Army construction projects are expected to comply by 2013. The proposed LID requirements also follow LID criteria stated in the LID Unified Facilities Code (UFC) 3-210-10N and EPA Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of EISA.

In addition to the LID Policy, the Army released a policy update in a memorandum on October 27, 2010, regarding sustainable design and development of any facility construction activities in the U.S. at active Army installations, Army Reserve Centers, Army National Guard Facilities, and Armed Force Reserve Centers, regardless of the funding source. In particular, Section 5f pertains to stormwater management and compliance with EISA Section 438, and it reiterates the installation of LID and minimizing site disturbance. Furthermore, Section 5g and 5h respectively state that any facility construction project is required to reduce its indoor potable water use by 30 percent and outdoor water use by 50% relative to projected baseline rates. Strategies used to reduce the potable water should follow American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 189.1 Sec 6 guidelines. The policy lists xeriscaping, rainwater retention, and water reuse and recycling as strategies to reduce potable water use. (Army 2010b)

1.2.3 CITY & COUNTY OF HONOLULU REGULATIONS

In addition to federal regulations regarding stormwater management, local flood control standards from Honolulu County also apply to the proposed SGS site. In particular, the Hawaiian Electric request for proposal (RFP) stated that surface drainage systems within SGS boundaries should be sized to convey the 10-year, 24-hour runoff to prevent roadway flooding and 50-year, 24-hour storm event to prevent equipment and building flooding (HECO 2013). The City and County of Honolulu further require development projects that disturb less than 100 acres to maintain predevelopment runoff volume and flow rates from the 10-yr design storm if the site ultimately discharges to a water body other than open coastal waters.

1.2.4 SUMMARY OF RELEVANT STORMWATER CRITERIA

The following summarizes pertinent regulations and policies for stormwater management:

- EISA Section 438 requires maintaining or restoring predevelopment hydrology for developments or redevelopments greater than 5,000 square feet (EISA 2007)
- EPA's Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act provides two options to reach EISA compliance by treating stormwater runoff quantity from:
    - Option 1) 95th percentile storm event or
    - Option 2) pre-development hydrology (EPA 2009). Any construction project on Federal land operated by the Army that requires stormwater management must incorporate LID practices (Army 2010a)
- LID techniques such as rainwater harvesting are encouraged for water reuse for irrigation and/or toilets (Army 2010a)
- A cost-benefit analysis must accompany all rainwater harvesting projects to demonstrate a favorable return on investment (ROI) over a 30-year period (Army 2010a)
- Traditional stormwater practices such as retention and detention ponds are discouraged by the Army (Army 2010a)
- Indoor potable water use should be reduced by 30 percent from baseline conditions in any Army facility (Army 2010b).
- Outdoor potable water use should be reduced by a minimum of 50 percent through strategies such as rainwater retention and water reuse at Army facilities (Army 2010b).

- Meet local flood control standards requiring that runoff volume from the 10-year design storm be limited to predevelopment values (City and County of Honolulu 2000). Furthermore, the 10-year, 24-hour storm discharge should be managed without flooding roadways and the 50-year, 24-hour discharge without flooding equipment and buildings at SGS (HECO 2013).

1.3 PROJECT DESCRIPTION

The proposed Schofield Generating Station is located on the Army's South Range Acquisition Area, which is adjacent to Schofield Barracks Main Post, near Wahiawa, Hawaii, as shown in Figure 1-1. The Army's Energy Initiatives Task Force (EITF), which was established to ensure Army energy security and sustainability, recommended the Schofield Barracks site as an ideal location for cost-effective, secure renewable energy management. The proposed 10.3 acre site is located on federally-owned land that would be leased to Hawaiian Electric for construction, ownership, operation and maintenance of a biodiesel-fired power plant. Six Wartsila multi-fuel capable engines are projected to provide a combined power of about 50 megawatts (MW), which will be transferred into the local grid by a new 46 kilowatt (kW) transmission line. The liquid biofuel will be stored on site in two aboveground fuel storage tanks, which will provide storage for 1.6 million gallons of fuel. In addition to the engines, the site will also contain selective catalytic reduction and oxidation catalyst systems. Stormwater runoff from the diesel tanks and lubricating oil equipment areas at SGS will be routed into water collection sumps. These sumps will routinely be checked for contamination from the equipment and will occasionally be pumped through an on-site oil water separator system. Primary potential contaminants include fuel and oil from the biodiesel engines and their accompanying equipment. Non-contaminated water will be subjected to stormwater management through LID solutions. Trucks will transport toxic stormwater for off-site treatment at an appropriate wastewater disposal facility. (HECO 2103)

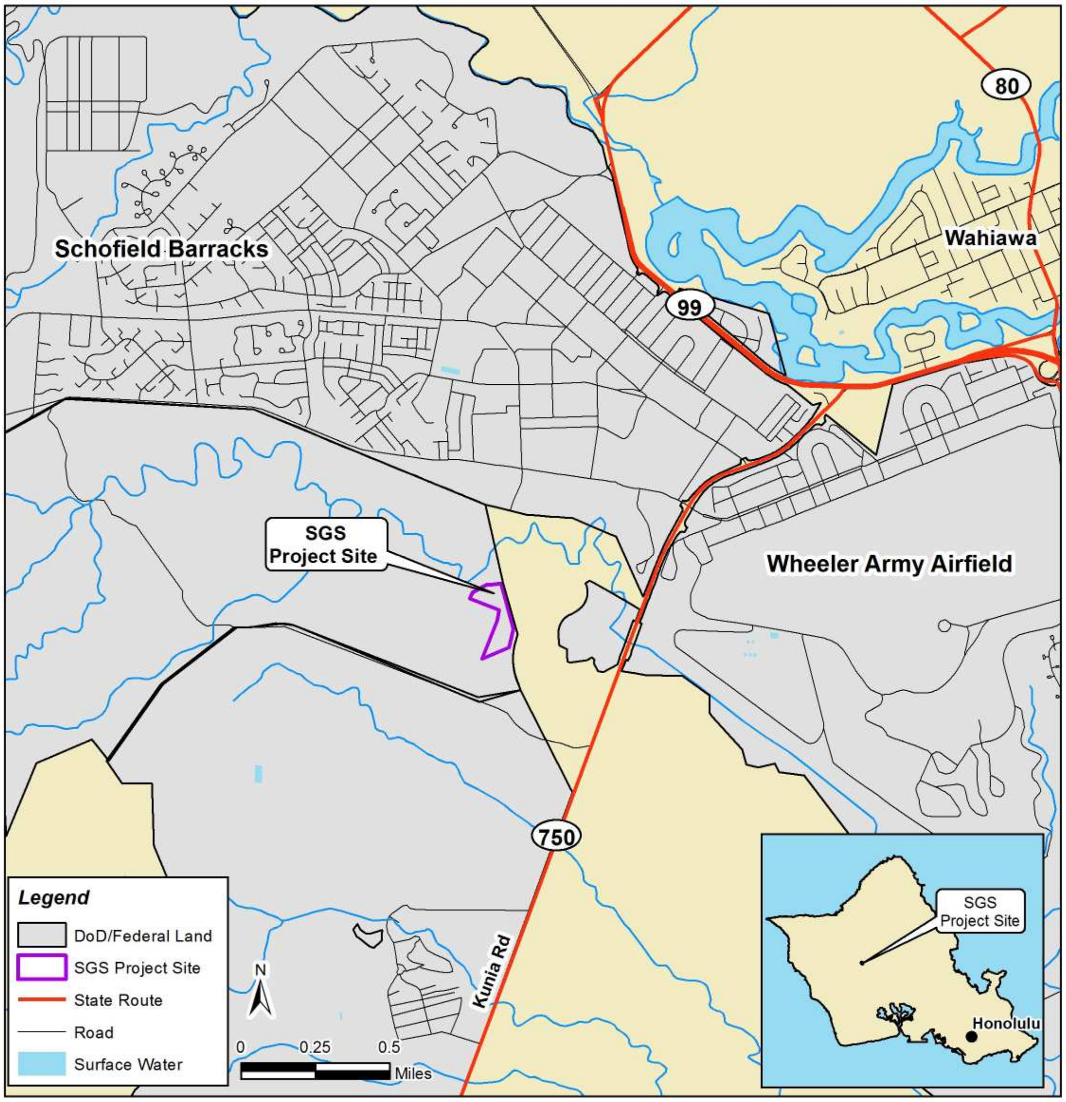


Figure 1-1: Location of proposed Schofield Generating Station

Based on UFC and the Army LID Policy, the Army encourages rainwater harvesting as a sustainable, land-efficient stormwater management option. The proposed SGSP RFP Appendix B Section 2.9 details water use for the site. Potable water will be used for the engine hall, control building, water treatment facility, sinks, men's and women's lavatories, showers, water fountains and emergency eyewash and shower stations. The potable water will be sourced from an existing U.S. Army Base potable water system (HECO 2013). The Initial Scope of Work Planning Package (ISOWPP) estimated that 500 gallons per day of City of Honolulu water would be necessary for service and potable needs for the site (USACE 2012). Per the Army policy updates from 2010, water harvesting will be studied for this site to determine if captured stormwater can be recycled for some of the proposed water uses in a cost-effective manner. In particular, this would help achieve the requirement of a 30 percent potable water reduction for indoor use and 50 percent reduction for outdoor use. This report will further discuss the volume of stormwater that could be captured and reused based on the site's climate and proposed impervious surfaces. Other LID options will also be analyzed to determine the optimal design for SGS.

1.4 RELEVANT LID PRINCIPLES

LID offers numerous benefits and advantages over the conventional approach to stormwater management. In short, LID is a more environmentally sound technology. LID protects environmental assets, protects water quality, and builds community livability by addressing runoff close to the source through intelligent site design to reduce volume and decentralize flows. This is usually best accomplished by creating a series of smaller retention or detention areas that allow localized filtration instead of carrying runoff to a remote collection area to be treated. The natural processes employed by LID practices allow pollutants to be filtered or biologically or chemically degraded before stormwater reaches local water bodies. Relevant LID practices to this study include bioretention BMPs and cistern BMPs for water reuse (Table 1-1).

Table 1-1: Summary of Stormwater Management Practices

Stormwater Management Practice	**Conventional Detention Pond**	**Bioretention and Infiltration Facilities**	**Rain Water Harvesting Cisterns**
Description	Basins designed to capture and slowly release runoff for flood control, channel protection, and water quality.	Basins designed to capture and infiltrate runoff. Engineered soils are often specified to improve infiltration and water quality.	Tanks designed to capture and store stormwater runoff. Water can be slowly drained or reused to offset potable water use.
Pollutant Removal Efficiency			
Sediment	Medium	High	N/A[1]
Metals	Low	High	
Hydrocarbons	Low	High	
Nutrients(TN & TP)	Low	Medium	
Bacteria	Medium	High	
Thermal Load	Medium	High	
Land Use Required	High	High	Low
Peak Runoff Attenuation	Yes	Yes	Yes
Runoff Volume Reduction	No	Yes	Yes
Costs	\$-\$\$	\$\$-\$\$\$	\$-\$\$
Operation & Maintenance	Medium	Medium-High	Medium-High
LID concept	No	Yes	Yes
Help achieve Army goals for 30% indoor & 50% outdoor potable water reductions?	No	No	Yes

[1] Rainwater harvesting pollutant removal is difficult to quantify since the influent pollutant concentrations from roofs (typical drainage area) are typically low, so the pollutant concentrations entering cisterns are often irreducible.

2 APPROACH & ANALYSIS

The following section presents relevant hydrologic and hydraulic methodologies to address the regulatory requirements summarized in Section 1. Results in this section will be synthesized into compliance recommendations in Section 3.

2.1 EISA COMPLIANCE

This section describes methodology to characterize site hydrology and identify the most cost-effective option for EISA compliance. The EPA's Storm Water Management Model (SWMM), version 5.0, was used to characterize existing and proposed hydrologic conditions and the EPA's System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN), version 1.2, model was used to simulate and optimize stormwater management practice performance. A detailed summary of model inputs and assumptions is provided in Appendix A.

2.1.1 BASELINE CONDITIONS

To evaluate runoff conditions and simulate prospective BMP performance for current and future conditions, several key data sets were processed and formatted for input into the model. The data sets required for this study were identified as land use (current and future), topography, soils, groundwater, and precipitation (Table 2-1).

Table 2-1: Model Input Data

Topography	
Proposed Site Area	10.3 acre
Proposed Site Impervious Area[1]	1.4 acre
Site Elevation Range AMSL[2]	860-886 feet
Average Site Slope	3.2%
Soils[3]	
Current Land Use	Cultivated
Existing Soil	HSG B
Minimum Infiltration Rate	0.2 inch/hour
Maximum Infiltration Rate	2.0 inch/hour
Average Saturated Hydraulic Conductivity	1 inch/hour
Climate Data[4]	
Precipitation Station	Wahiawa Dam 863
Temperature Station	Schofield East

[1] Based on conceptual plans; [2] Above Mean Seal Level (AMSL); [3] Obtained from the National Resources Conservation Services (NRCS) Soil Survey Geographic (SSURGO) database; [4] collected from National Climatic Data Center (NCDC) Climate Data Online

Soil borings conducted onsite confirmed SSURGO classification of site soils as clayey silts (HECO 2013). To ensure conservative analyses, the saturated hydraulic conductivity of site soils was assumed equal to the minimum infiltration rate for HSG B soils (0.2 inch/hour), as recommended in SWMM User's Manual produced by EPA (Huber and Dickinson 1988). Both of the climate stations' data were combined due to their close proximity to each other and the proposed SGS site to create 11 years (2001-2011) of continuous temperature and precipitation data for modeling purposes. Pan evaporation rates were estimated for the site by averaging the evaporation rates measured at the three closest monitoring stations in Ekern and Change (1985). Pan evaporation was converted to reference evapotranspiration using the formula recommended in Snyder et al. (2005).These data were input to SWMM to generate runoff timeseries data for the baseline (predevelopment) conditions. Hydrology was simulated for an 11-year period from 2001 through 2011 and also for the 10-year, 24-hour average recurrence interval storm event and the 95th percentile storm event.

2.1.2 EISA OPTIONS

<u>EISA Option 1</u>

Option 1 for meeting EISA regulations requires that runoff from the 95th percentile storm be fully contained. Using the local precipitation data, the 95th percentile storm was calculated by sorting the available data from largest to smallest recorded precipitation over a 24-hour period then eliminating values less than or equal to 0.1 inch according to technical guidelines described in EPA's technical guidance document. A statistical analysis was performed on the organized data to find the 95th percentile storm.

To generate a conservative runoff estimate for comparison with Option 2, the impervious surface was assumed to have no depression storage in the Option 1 analysis. The effective BMP volume needed for treating a certain amount of increased imperviousness in a subwatershed was calculated as the area of the increased imperviousness in the conceptual site layout multiplied by the 95th percentile storm depth. For purpose of comparison, all runoff was assumed to be captured by an arbitrary BMP with a uniform surface storage depth of 4 feet (consistent with following Option 2 analyses). The total BMP volume required under Option 1 was compared to results from the following Option 2 analysis.

<u>EISA Option 2</u>

The SUSTAIN model in Option 2 provides a continuous simulation alternative to the 95th percentile storm approach under Option 1. During the continuous simulation, long-term rainfall characteristics, evapotranspiration from BMPs, and detention effects from BMPs are all considered. Runoff from subwatersheds is computed using hydrologic response unit (HRU) timeseries that were generated for each HRU using SWMM.

BMP Representation in SUSTAIN

Infiltration BMPs are effective measures to restore post-development runoff conditions to the predevelopment level. The SUSTAIN model can help quantify the hydrologic benefits from BMP implementation. As subwatershed runoff is routed through an infiltration BMP, porous spaces in BMPs provide total volume and peak flow reduction control. The degree of hydrologic benefit varies as the size of the BMPs change. As BMPs are implemented for continuous simulation, percolation of infiltrated water to the natural soil from the bottom of BMPs must be accounted for. In addition to infiltration BMPs, SUSTAIN simulates rainwater harvesting by using cisterns to capture runoff and control release through orifices. Cisterns can be sized to provide total volume and peak flow reduction control, and specific water volumes can be allocated for reuse for toilet flushing or irrigation, for example. For the purpose of comparing Option 1 to Option 2, runoff generated from the new impervious surfaces proposed in the conceptual site layout was routed to an arbitrary infiltration BMP consistent with characteristics applied to Option 1 analysis.

Compliance Option Selection

The 95th percentile rainfall depth was calculated to be 1.8 inches (Figure 2-1), which equates to a required BMP storage volume of 0.21 acre-feet to capture and infiltrate all associated runoff from the new impervious surfaces proposed in the conceptual site layout (HECO 2013). Option 2 for meeting EISA regulations requires that future runoff conditions match the pre-development hydrology during long term simulation, and the resulting volume that would need to be captured by BMPs such that the site experiences no net increase in runoff is 0.31 acre-feet (Table 2-2). In order to meet EISA compliance in a cost-effective manner, Option 1 is the optimal criteria because it allows a 34% smaller BMP footprint than Option 2. The required treatment volume for the 95th percentile event is greater than local Honolulu water quality volume requirements (0.146 acre-feet from the 1-inch event, as calculated using the simple method), so the recommended EISA compliance strategy is assumed to satisfy local water quality requirements (City and County of Honolulu 2000).

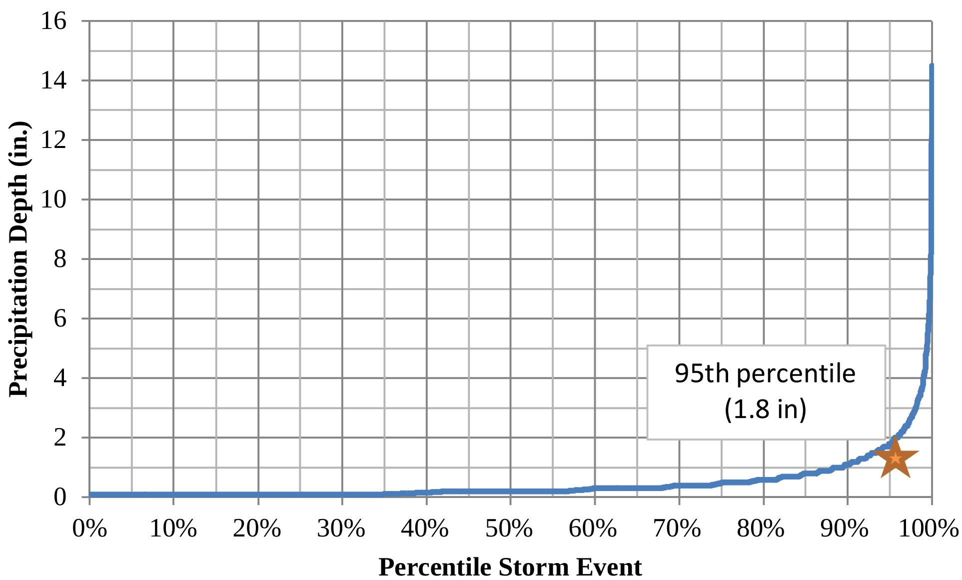


Figure 2-1. Percentile distribution of storm events at proposed SGS (excluding daily rainfall depths < 0.1 inch)

Table 2-2: EISA options comparison for compliance selection

	Option 1 (Retain Onsite 95th Percentile Volume)	**Option 2 (Match Predevelopment Hydrology)**
Required Storage Volume for Compliance (Arbitrary BMP[1])	0.21 acre-feet	0.31 acre-feet
Normalized BMP Footprint for Compliance (Arbitrary BMP[1])	0.037 acre / acre impervious	0.056 acre / acre impervious

[1]Assumes infiltration into native soils from arbitrary infiltration basin with uniform surface storage depth of 4 feet

2.1.3 EISA COMPLIANCE ALTERNATIVES

The following design options are proposed alternative solutions for stormwater management at the proposed SGS site. Based on modeling results, the two alternative designs were compared to select a best design that is compliant with EISA Option 1, cost-effective for stormwater management, and promotes the Army's goal for a sustainable future.

Alternative 1 – Centralized Infiltration Basin

Original proposed site plans from Hawaiian Electric include a detention pond as the sole design for stormwater management on the proposed SGS site. While this design would capture volume from the proposed impervious surface and reduce stormwater peak discharge, it would provide little *volume* reduction and water quality improvement; therefore, it would not meet EISA requirements. To achieve compliance with EISA Option 1 and provide enhanced water quality treatment, aesthetics, and sustainability, the proposed detention pond was adapted to function as an infiltration basin in Alternative 1. The facility would capture water on the surface and rely on infiltration into native soils. Surface soils would be tilled to a depth of 12 to 24 inches and amended with at least 2 inches of organic or mineral topsoil amendments per USEPA (2011) to enhance the physical structure and the chemical and biological properties critical to infiltration. To determine the most cost effective configuration, SUSTAIN's optimization algorithm was configured to adjust the ponding depth and surface area of the infiltration facility until the minimum cost design (compliant with Option 1) was identified.

Alternative 2 – Distributed LID BMPs

The Alternative 2 design consists of a combination of LID practices (namely bioretention and rainwater harvesting cisterns) distributed throughout the site. SUSTAIN was used to optimize BMP size with the goal of balancing costs and effectiveness for stormwater management. Modeled under this alternative would be multiple BMPs that could be grouped or spread throughout the site to capture runoff and treat it efficiently.

Comparison of Alternatives

Figure 2-2 illustrates the results of modeling Alternative 1 and Alternative 2. Alternative 1 was predicted to cost approximately 18% less than Alternative 2 based on planning-level construction cost functions.

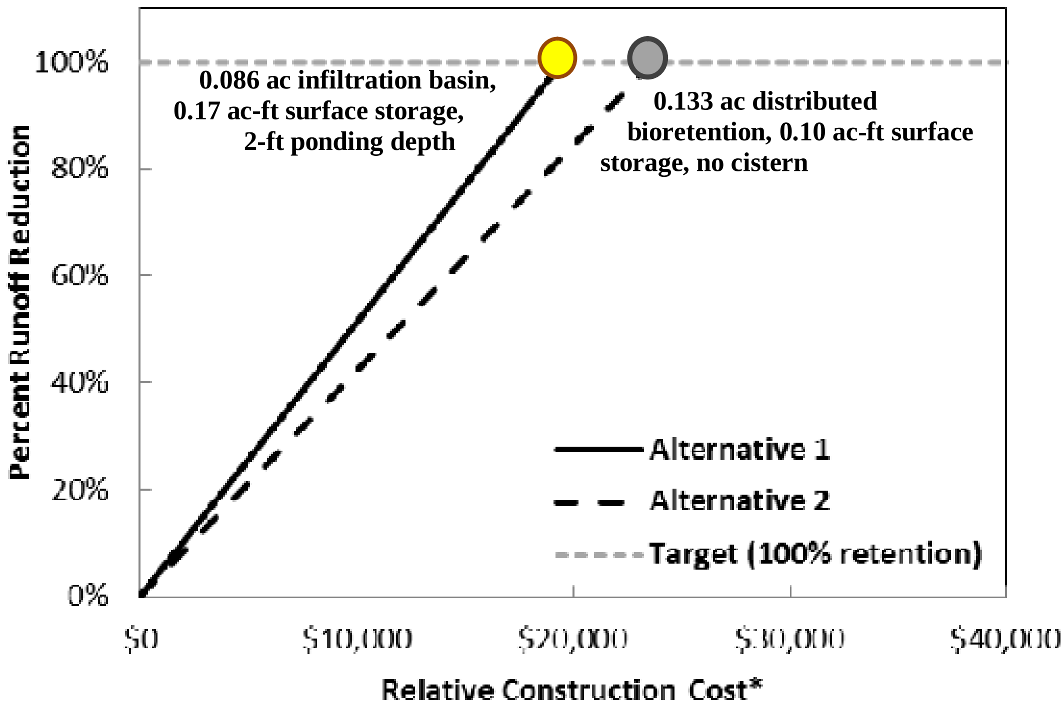


Figure 2-2. Cost effectiveness comparison between Alternative 1 and Alternative 2. *Modeled construction cost functions are relative and should not be used for engineering cost estimation.

2.2 CITY AND COUNTY OF HONOLULU STORM DRAINAGE STANDARDS COMPLIANCE

Additional retention volume will be required to comply with local flood control standards. Per City and County of Honolulu Rules Relating to Storm Drainage Standards (2000), the proposed BMP must be sized to maintain predevelopment runoff volume and discharge from the 10-year design storm event. For discharge-based analyses, the design storm duration should be equivalent to the time of concentration (the duration required for runoff to reach the drainage area outlet from the most hydraulically remote point). The time of concentration for the site was 5 minutes, as calculated using the methods in City and County of Honolulu Rules Relating to Storm Drainage Standards (2000) and the corresponding adjusted 10-year rainfall intensity was 7.6 inch/hour. Runoff coefficients were selected from Table 1 in City and County of Honolulu Rules Relating to Storm Drainage Standards (2000) and the rational method was used to predict the design storm peak discharge from predevelopment and developed conditions. Results are summarized in Table and a detailed summary of model inputs and assumptions is provided in Appendix A.

In addition to discharge, the volume of runoff from the design storm must also be maintained at or below predevelopment conditions to satisfy local regulations. For volume-based analyses, a design storm duration of 1-hour was selected because it is featured prominently throughout the City and County of Honolulu Rules Relating to Storm Drainage Standards (2000). To fully retain and infiltrate the excess runoff volume from the 10-year design storm associated with post-development conditions, 0.241 acre-feet of surface storage would be required, as summarized in Table 2-3.

Table 2-3. Results of Rational method analyses relating to local flood control requirements

Flow Based Analysis	
Predevelopment 10-year, 5-minute Runoff Discharge	15.7 cfs
Post-development 10-year, 5-minute Runoff Discharge	23.5 cfs
Excess Runoff Discharge	7.8 cfs
Volume-Based Analysis	
Predevelopment 10-year, 1-hour Runoff Volume	0.472 acre-feet
Post-development 10-year, 1-hour Runoff Volume	0.713 acre-feet
Excess Runoff Volume	0.241 acre-feet

2.3 ARMY LID POLICY COMPLIANCE

As previously discussed, Army LID policy updates require the consideration of rainwater harvesting and reuse in all new designs. Furthermore, a 30% reduction in indoor water use and 50% reduction in outdoor water use are mandated under these directives. In order to meet these policies, rainwater harvesting was analyzed as an alternative solution to the proposed water line. According to the Hawaiian Electric RFP, the project is expected to use approximately 500 gallons of service and potable water uses. Currently, the water is to be piped in from a future 2-inch water line in conjunction with the proposed wastewater lift station.

The North Carolina State University Rainwater Harvester Model (NCSU 2008) was used to simulate various long-term continuous water reuse scenarios. Eleven years of rainfall data from 2001 to 2011 were used to drive the model and it was assumed that rooftop runoff would be collected from the approximately 15,000 square foot metal roof of the engine hall specified in the conceptual site layout (HECO 2013). An effectiveness curve was generated comparing cistern size to potable (municipal) water use reduction. The cost-effective cistern volume to comply with Army directives was selected from this curve.

A 30-year ROI analysis was performed assuming an annual linear increase in unit water prices. Future water prices were projected based on published historic rates and fees for nonresidential purposes provided at Honolulu Board of Water Supply (2013). Captured water could be used for toilet/water closet use, irrigation, equipment washing, and possibly emergency firefighting water supply. Filtration and disinfection systems can be used treat harvested water for potable use, but the majority of demand tends to be non-potable.

3 RECOMMENDATIONS

The following design options are proposed solutions for compliance with EISA (2007), City and County of Honolulu Storm Drainage Standards (2000), and Army LID Policy (2010a) at the proposed SGS site.

3.1 EISA COMPLIANCE RECOMMENDATIONS

Analyses summarized in Section 2.1.3 indicated that Alternative 1 (centralized infiltration basin) would likely offer the most cost-effective solution for compliance with EISA Option 1. Figure 3-1 predicts the required infiltration basin footprint depending on the actual imperviousness in the final site plans (the conceptual site layout used for preceding calculations was considered the baseline condition). Note that the required storage volume is greater than the volume indicated in

Table 2-2 because these analyses used the optimum ponding depth of 2 feet (versus the arbitrary 4-foot ponding depth used for comparison of Option 1 and Option 2). The required infiltration basin footprint for the baseline condition is 0.086 acre 67% smaller than the detention basin shown on the current conceptual site layout; HECO 2013).

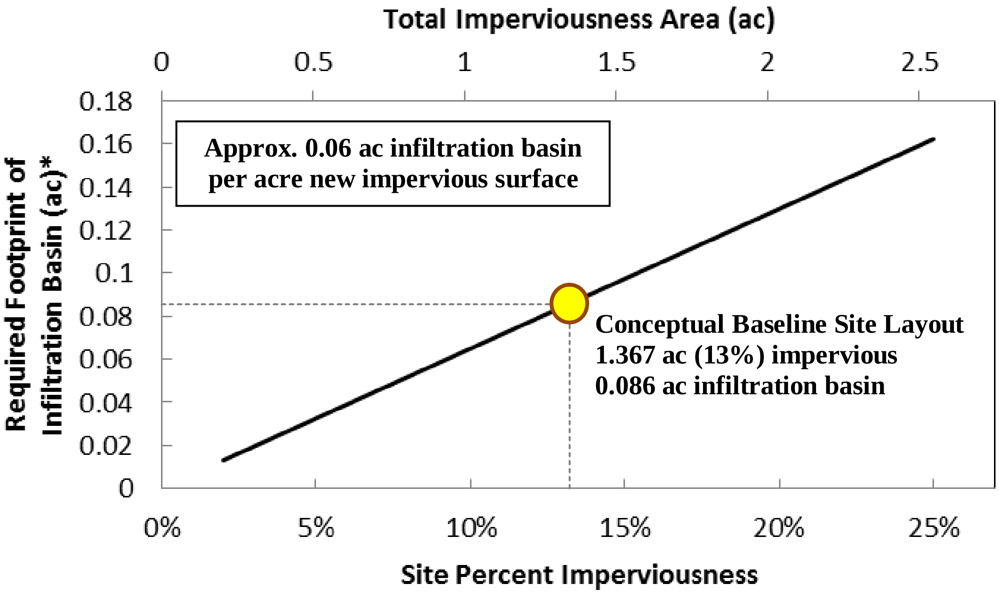


Figure 3-1. Predicted infiltration basin footprint required to retain 95th percentile runoff volume from new impervious surfaces. *Assumes 2-foot surface ponding depth and infiltration into native soils tilled to a depth of 12-24 inches and amended with 2 inches of mineral or organic topsoil amendment.

3.2 CITY AND COUNTY OF HONOLULU STORM DRAINAGE STANDARDS COMPLIANCE RECOMMENDATIONS

The retention volume for compliance with local flood control standards (0.24 acre-feet) exceeds the retention volume required for EISA compliance (0.17 acre-feet); therefore, the excess flood control volume (0.071 acre-feet) must be added to the infiltration basin. This additional volume translates to increasing the depth of the proposed basin by 0.83 feet to a total depth of 2.83 feet or increasing the footprint of the basin by 0.036 acre (as illustrated in Figure 3-2 based on the baseline conditions in the current conceptual site layout provided in the Hawaiian Electric RFP dated May 1, 2013). It is recommended that the footprint of the basin be increased in order to maximize the surface area available for infiltration. Flood control retention volume sizing will vary depending upon the final site layout, routing, and preferred infiltration basin design configuration.

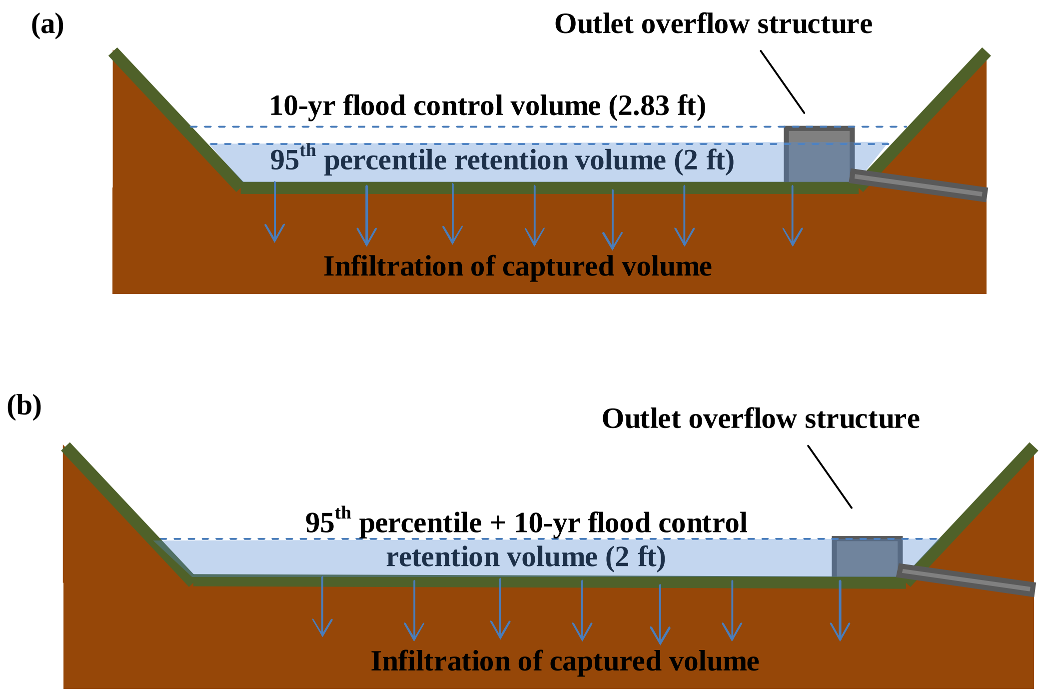


Figure 3-2. Conceptual schematic of possible basin configurations for EISA and flood control compliance, including (a) increased surface ponding depth and (b) increased footprint (recommended). Not to scale.

3.3 ARMY LID POLICY COMPLIANCE RECOMMENDATIONS

Results of rainwater harvesting and reuse optimization modeling are shown in Figure 3-2. The optimum rainwater harvesting solution was predicted to offset 71% of water demand at the facility with no backup (municipal) water (although a backup system is recommended to ensure consistent supply during dry periods).

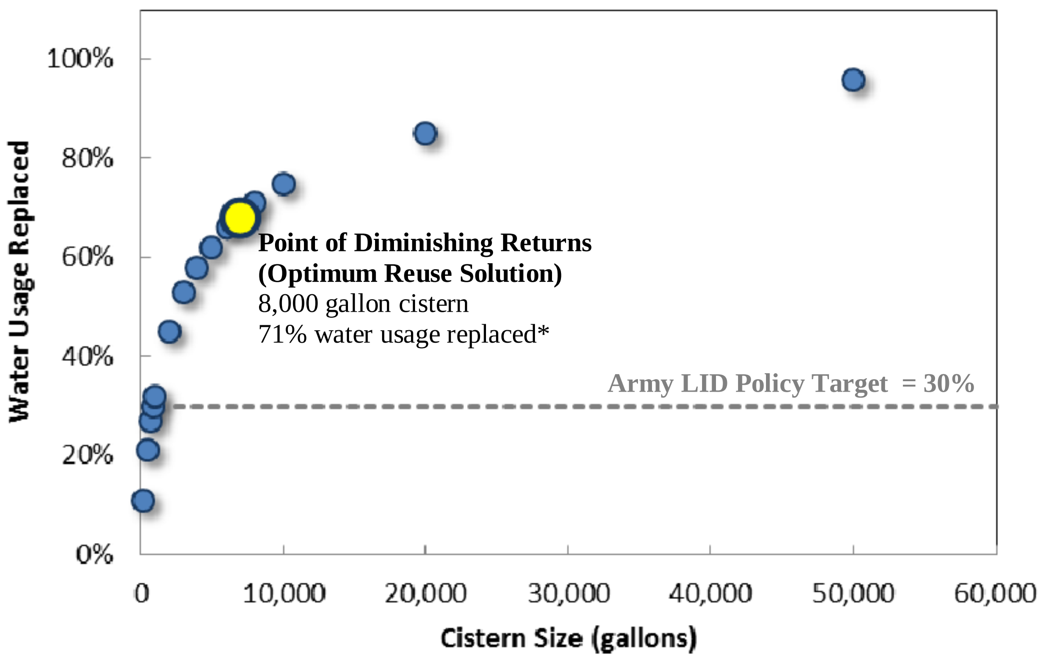


Figure 3-2. Rainwater harvesting and reuse cost effectiveness curve. *Assumes no backup water supply

Because a backup water system will likely be installed to ensure consistent supply, the 8,000-gallon cistern was modeled with a backup water supply, and Figure 3-3 was generated based on extrapolation of Honolulu water cost data (including projected increased costs). The approximate payback period for the optimal cistern size is 11 years.

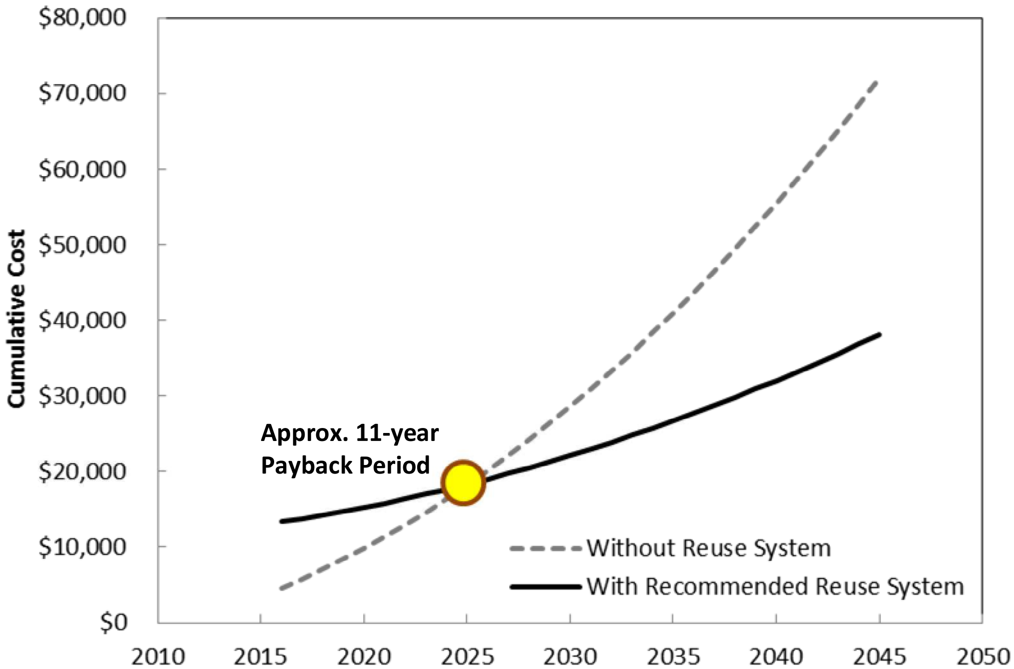


Figure 3-3. 30-year ROI analysis for rainwater harvesting and reuse system.

3.4 SUMMARY OF COMPLIANCE RECOMMENDATIONS

Table 3-1 synthesizes the design configuration that, based on modeling results, would comply with EISA Option 1, meet City and County of Honolulu Storm Drainage Standards for flood control, and follow Army's LID policies on a 30% potable water reduction through to rainwater harvesting. The design configuration of an infiltration basin and cisterns will provide cost-effective stormwater management while promoting the Army's goal of a sustainable future.

Table 3-1. Recommended compliance solution for retaining 95th percentile runoff volume from new impervious surface. New pervious surfaces were assumed to generate no net increase in runoff volume.

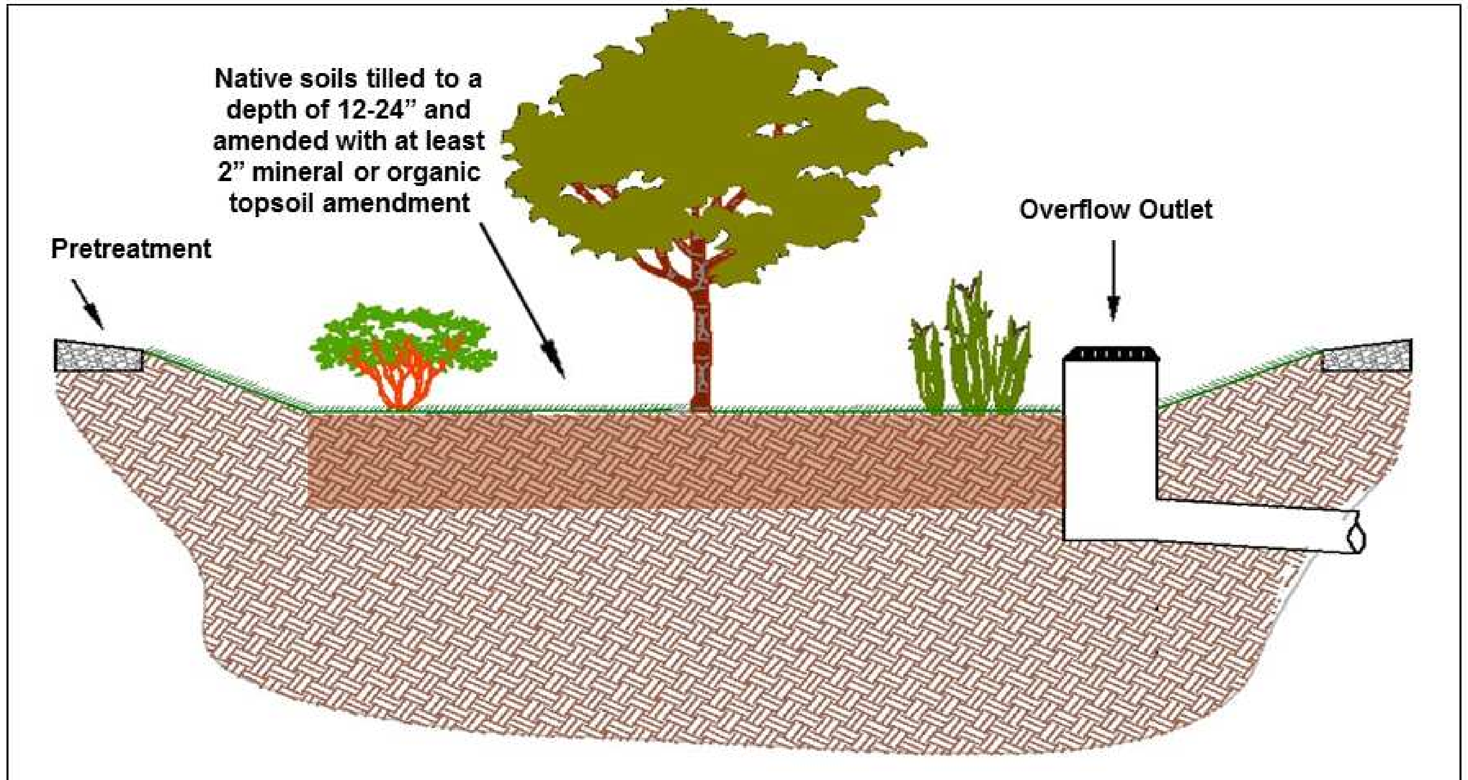
	Infiltration Basin[1]			Rainwater Harvesting Cistern
	Min.	**Baseline**	**Max.**	
Impervious Drainage Area[2]	0.61 acre (6% of site)	1.4 acre (13% of site)	2.1 acre (21% of site)	0.35 acre rooftop (3.4% of site)
Surface Storage Volume[3]	0.11 acre-feet	0.24 acre-feet	0.36 acre-feet	8,000 gallon
Footprint[3]	0.052 acre	0.12 acre	0.18 acre	varies
Surface Ponding Depth	2 feet			

[1]Assumes amendment of native soils with 2 inches of loamy sand or organic topsoil and ripping or tilling soils to a depth of 12-24 inches.
[2]To ensure capture of the 95th percentile runoff volume, the drainage area to the infiltration basin includes rooftop area that directly drains to cistern. In the event that the cistern is full or taken offline for maintenance, the recommended basin dimensions will have sufficient volume to capture the 95th percentile runoff volume from all new impervious surfaces and maintain compliance with EISA criteria.
[3] Surface storage volumes and footprints include additional volume and area for City and County of Honolulu Storm Drainage Standards compliance.

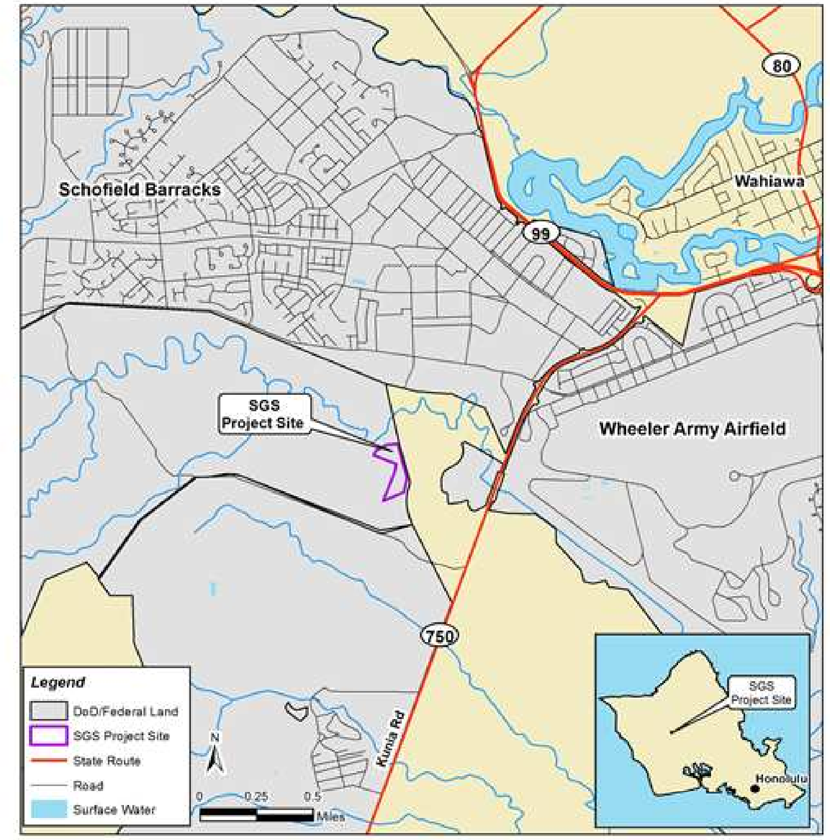
BMP FACT SHEETS

The following fact sheets can be used to guide preliminary and final design of stormwater control and LID features at the SGS site.

BMP Factsheet 1 – Infiltration Basin
EISA COMPLIANCE – ALTERNATIVE 1
SITE: PROPOSED SCHOFIELD GENERATING STATION, U.S. ARMY GARRISON, HAWAII



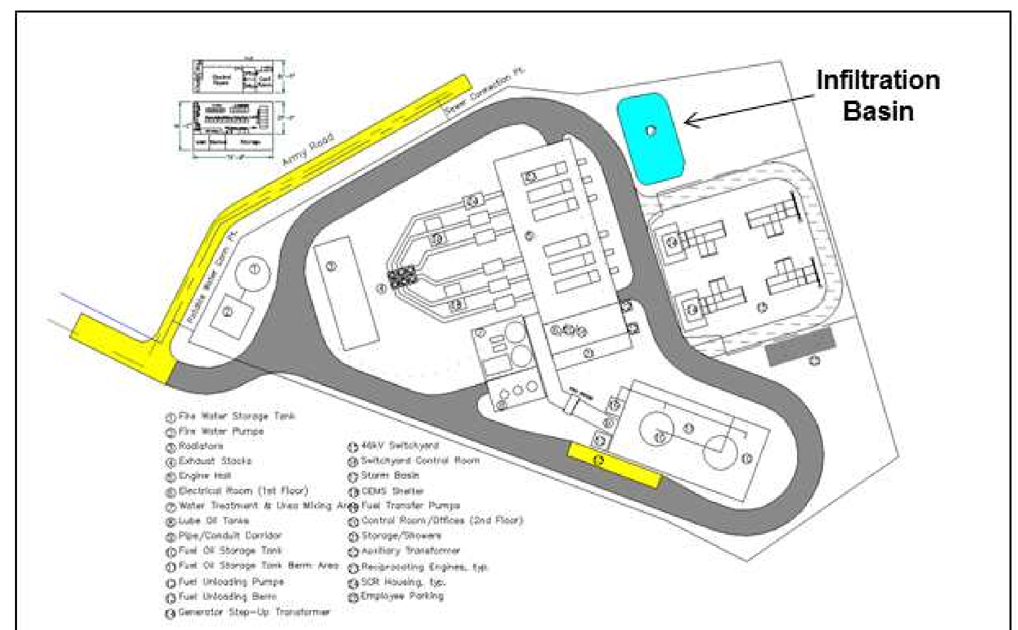
Conceptual Infiltration Basin Side Profile



INFILTRATION BASIN SPECIFICATIONS	
Impervious Drainage Area	1.4 ac (13% of site)
Normalized BMP Footprint for Compliance	0.06 ac / ac impervious
Infiltration Basin Footprint*	0.12 ac
Surface Ponding Depth	2 ft
Surface Storage Volume	0.24 ac-ft
BMP Dimensions	0.12 ac basin with 2 foot ponding depth

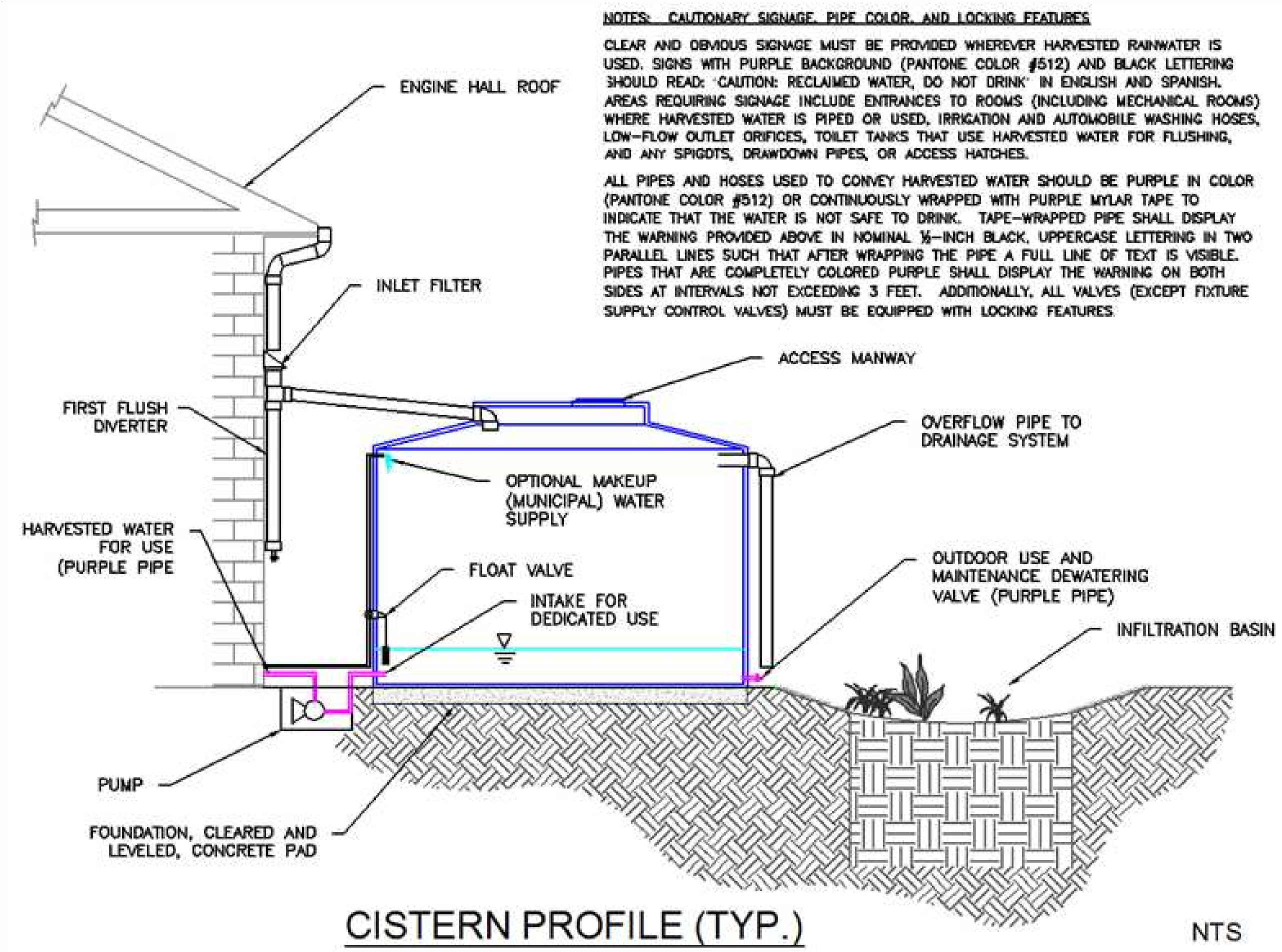
Proposed BMP Considerations:
Infiltration basins provide stormwater management by providing large storage area for volume and peak flow control. A pretreatment area allows for stormwater runoff to first be treated through energy dissipation and sediment settling. Pretreatment is typically provided by rocky forebays or vegetated swales and filter strips. Infiltration basins should be routinely maintained and inspected for optimal performance. The basin should include emergency overflow structures for high volume storm and/or frequent events. Surface soils should be amended with at least 2 inches of organic or mineral topsoil amendment, and the soils should be ripped or tilled to a depth of 12 to 24 inches to enhance infiltration and ensure establishment of native plants.

* Infiltration basin footprint includes 0.036 ac for 10-yr storm event excess runoff per City and County of Honolulu Storm Drainage Standards Compliance

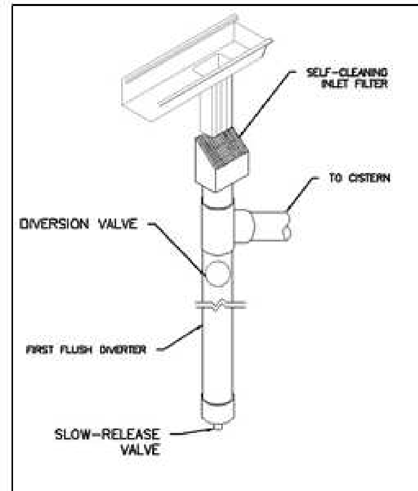


Top Image: Site Location on Oahu Island in Hawaii;
Bottom Image: Proposed Site Plan for Schofield Generating Station

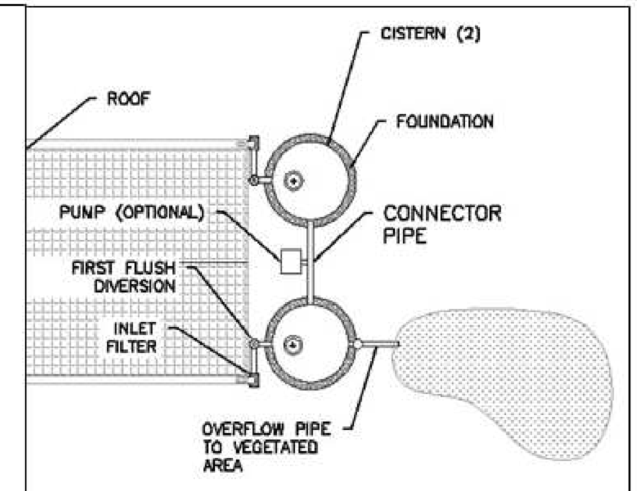
BMP FACTSHEET 2 – RAINWATER HARVESTING
ARMY LID POLICY COMPLIANCE
SITE: PROPOSED SCHOFIELD GENERATING STATION, U.S. ARMY GARRISON, HAWAII



CISTERN PROFILE (TYP.)



PRETREATMENT DETAIL (TYP)



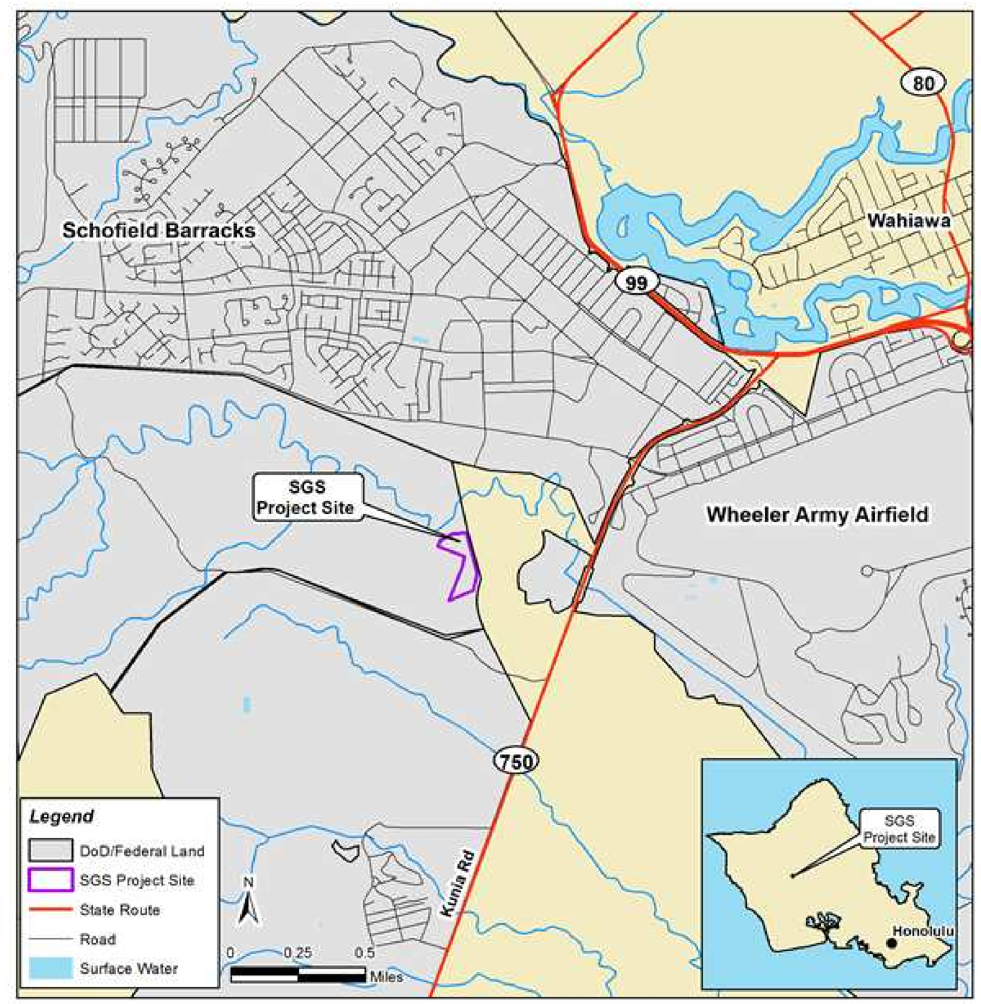
CISTERN PLAN VIEW (TYP)

WATER USE STATISTICS			
Anticipated Potable/ Service Water Demand	500 gal/day	Army Indoor Water Use Reduction Goal	30%
Return on Investment Payback Period	11 years*	Average Annual Water Use Offset by Cistern	71%
Anticipated Water Uses	Lavatory flushing, building and equipment washing, sinks, showers.		

RAINWATER HARVESTING CISTERN SPECIFICATIONS	
Impervious Drainage Area	0.35 ac (3.4% of site) rooftop of engine hall
Cistern Storage Capacity	8,000 gal
BMP Dimensions	Sizing will vary based on final site design plans.

Proposed Retrofit Consideration:
Cisterns should be placed near a roof downspout, but can also be located remotely if a "wet conveyance" configuration is used. The structural capacity of soils should be investigated to determine whether a concrete foundation is needed; generally concrete is required for cisterns exerting greater than 2,000 pounds per square foot. Cisterns are available commercially in numerous sizes, shapes, and materials. The configuration will be determined by available space, intended reuse strategy, and aesthetic preference. An overflow mechanism is important to prevent water from backing up onto rooftops—overflow should be conveyed in a safe direction away from building foundations. Filtration and disinfection systems are commercially available.

*Based on planning-level cost estimate and projected annual increases in Honolulu municipal water unit prices and fees



General site area in relation to Schoefield Barracks; Site location on Oahu Island in Hawaii

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Appendix A. HYDROLOGIC INPUTS & ASSUMPTIONS

This Appendix presents relevant assumptions, inputs, and calculations to support the findings in the preceding report. All hydrologic calculations are based on the data available and should be verified with onsite testing. Assumptions and calculations should be adjusted to reflect the final site layout.

A.1 SWMM LAND SIMULATION ANALYSES

The following inputs were used to generate runoff timeseries data for predevelopment and developed land use conditions. Runoff timeseries files represent runoff generated from a given hydrologic response unit (HRU) over a specified climatic period; these files were ultimately used to drive hydrologic analysis scenarios in SUSTAIN. Tables A1-A5 present the relevant hydrologic inputs and assumptions

Table A2. Input hydrologic parameters for predevelopment HRU runoff timeseries generation

Predevelopment Input Land Parameters – Pineapple Plantation		Unit	Source/Assumption
Area	1	ac	Time series generated on a per-acre unit basis
Site width	152	ft	Scaled proportionally to actual site length of 430 ft
Slope	3.2	%	Contours in conceptual site plan
Imperviousness	0	%	
Surface Roughness Manning's N	0.13		Range (natural), EPA SWMM Manual
Depressional Storage Depth	0.2	in	Pasture, EPA SWMM Manual
Infiltration Method	Horton		
Horton Max. infiltration	2.0	in/hr	Based on silty HSG B soils from NRCS SSURGO, as verified by site-specific geotechnical analysis from RFP; Wanielista, Kersten, and Eaglin (1997); and Viessman and Lewis (2003)
Horton Min. Infiltration	0.2	in/hr	Based on silty HSG B soils from NRCS SSURGO, as verified by site-specific geotechnical analysis from RFP; Wanielista, Kersten, and Eaglin (1997); and Viessman and Lewis (2003)
Horton Decay Rate Constant	4	/hr	Based on silty HSG B soils from NRCS SSURGO, as verified by site-specific geotechnical analysis from RFP; Wanielista, Kersten, and Eaglin (1997); and Viessman and Lewis (2003)

Table A3. Input hydrologic parameters for generation station engine hall roof HRU runoff timeseries generation

Developed Land Parameters – Engine Hall Roof		Unit	Source/Assumption
Area	1	ac	Time series generated on a per-acre unit basis
Site width	209	ft	Assumed square HRU
Slope	15	%	Scaled from conceptual building layout in RFP
Imperviousness	100	%	
Surface Roughness Manning's N	0.011		Smooth metal roof, EPA SWMM Manual
Depression Storage Depth	0.01	in	EPA SWMM Manual
Infiltration Method	Curve Number		
Runoff Curve Number	98		Impervious

Table A4. Input hydrologic parameters for all other impervious HRU (driveways, parking lots, utility structures) runoff timeseries generation

Developed Land Parameters – Other Impervious		Unit	Source/Assumption
Area	1	ac	Time series generated on a per-acre unit basis
Site width	209	ft	Assumed square HRU
Slope	3.2	%	Assumed average site slope was maintained
Imperviousness	100	%	
Surface Roughness Manning's N	0.011		Smooth metal roofs and smooth asphalt, EPA SWMM Manual
Depressional Storage Depth	0.05	in	EPA SWMM Manual
Infiltration Method	Curve Number		
Runoff Curve Number	98		Impervious

Table A5. Climatology and precipitation inputs

Input	Resolution	Period	Source
Precipitation – Long Term	Hourly	01/01/2001-12/31/2011	NCDC, Wahiawa Dam Weather Station
Precipitation – Design Storm	Hourly	24 hours	Distributed design storm depth over 24-hr period using Type I rainfall distribution
Temperature	Daily minimum/ maximum	01/01/2001-12/31/2011	NCDC, Schofield Barracks Weather Station
Wind Speed	n/a	n/a	Assumed 0, SWMM default

Table A6. Mean daily pan evaporation (in/day) from three closest monthly pan evaporation stations (815.00, 820.20, 851.00; Ekern and Chang 1985)

Jan	Feb	Mar	Apr	May	Jun
0.144	0.163	0.186	0.199	0.226	0.257
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
0.256	0.255	0.228	0.192	0.153	0.134

A.2 SUSTAIN ANALYSES

SUSTAIN was used to simulate BMP hydrologic performance, compare EISA Option 1 and Option 2, and as a decision support tool for determining the cost-effective BMP configuration. The following site-specific assumptions were incorporated into the modeling framework.

Table A7. Input parameters for SUSTAIN modeling of infiltration BMPs

BMP Parameter	Input		Unit	Source/Assumption
	Infiltration Basin	Bioretention		
Width	75	10	ft	Arbitrary, detention basin width from conceptual site layout
Length	Varied (0-150)	Varied (0-4200)	ft	Decision variable for optimization, range reflects available implementation area at proposed project site
Overflow Outlet Height	Varied (1-4)	0.75	ft	Outlet height was a decision variable for infiltration basin optimization; 9 inches represents recommended average ponding depth for bioretention
Weir Width	36		ft	Arbitrary, assumed flow will not be limited by outlet hydraulics
Soil Media Depth	2		in	Assumed amend top 2-inches with sandy loam topsoil
Soil Media Porosity	0.35		vol/ vol	Based on Brown et al. 2013
Soil Media Field Capacity	0.25		vol/ vol	Based on Brown et al. 2013
Soil Media Wilting Point	0.1		vol/ vol	Based on Brown et al. 2013
Underlying Soil Saturated Hydraulic Conductivity	0.2		in/hr	Minimum in range given by NRCS, as recommended in EPA SWMM Manual
Infiltration Method	Horton			
Horton Max. infiltration	2.0		in/hr	Based on silty HSG B soils from NRCS SSURGO, as verified by site-specific geotechnical analysis from RFP; Wanielista, Kersten, and Eaglin (1997); and Viessman and Lewis (2003)
Horton Min. Infiltration	0.2		in/hr	Based on silty HSG B soils from NRCS SSURGO, as verified by site-specific geotechnical analysis from RFP; Wanielista, Kersten, and Eaglin (1997); and Viessman and Lewis (2003)
Horton Decay Rate Constant	4		/hr	Based on silty HSG B soils from NRCS SSURGO, as verified by site-specific geotechnical analysis from RFP; Wanielista, Kersten, and Eaglin (1997); and Viessman and Lewis (2003)

Table A8. Input parameters for SUSTAIN modeling of cisterns

BMP Parameter – Infiltration Basin		Unit	Source/Assumption
Width	30	ft	Arbitrary
Length	Varied (0-80)	ft	Based on available area along engine hall
Overflow Outlet Height	10	ft	Arbitrary
Weir Width	1	ft	Arbitrary, assumed flow will not be limited by outlet hydraulics
Daily Use	500	gal/day	Based on anticipated potable/service water use specified in RFP

Table A9. Mean daily reference evapotranspiration (in/day) derived from three closest monthly pan evaporation stations (815.00, 820.20, 851.00; Ekern and Chang 1985). Derived using methods in Snyder et al. (2005).

Jan	Feb	Mar	Apr	May	Jun
0.116	0.131	0.149	0.158	0.178	0.200
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
0.200	0.199	0.180	0.153	0.123	0.108

A.3 LOCAL FLOOD CONTROL & WATER QUALITY VOLUME HYDROLOGIC & HYDRAULIC ANALYSES

The following calculations summarize flood control analyses per recommended methods in City and County of Honolulu Rules Relating to Storm Drainage Standards (2000).

Recurrence interval of 10 years used since the contributing drainage area to the storm water facility is less than 100 acres. Rational method used since the contributing drainage area to the storm water facility is less than 100 acres.

Average 10-year, 1-hour rainfall intensity for site area = 2.75 in/hr (Plate 1)

Runoff coefficient determined by assuming C = 0.95 for impervious areas and C = 0.20 for existing areas.
Pre-development runoff coefficient = 0.20 (Table 1 – Band 4)
Post-development impervious surface = 1.4 acres
Post-development pervious surface = 8.9 acres
Composite post-development runoff coefficient revised = 0.30

Time of concentration (use Plate 5)
Use lower curve (areas with little or no cover)
L = 811 feet
S = 0.032
K = 4,531
Tc = 5 minutes

Design rainfall intensity (use Plate 4)
Average rainfall intensity (from Plate 1) x Correction Factor (from Plate 4)

Design rainfall intensity = 2.75 in/hr x 2.75
Design rainfall intensity = 7.6 in/hr (for 5 minute duration)

Pre-development Q10 = (0.20) x (7.6 in/hr) x (10.3 ac)
Pre-development Q10 = 15.7 cfs

Post-development Q10 = (0.30) x (7.6 in/hr) x (10.3 ac)
Post-development Q10 = 23.5 cfs

If peak flow mitigation is required, then the 10-year peak flow must be mitigated from 23.5 cfs to 15.7 cfs or lower.

*** To determine the required detention volume, the 1-hour rainfall duration was selected for the volumetric calculations since the 1-hour storm is prominently featured in the regulations.

Pre-development 10-year runoff volume = (0.20) * 2.75 in * 10.3 acre
Pre-development 10-year runoff volume = 0.472 acre-feet

Post-development 10-year runoff volume = (0.30) * 2.75 in * 10.3 acre
Post-development 10-year runoff volume = 0.708 acre-feet

*** This analysis approach results in an excess runoff volume of 0.236 acre-feet

This excess runoff volume total is greater than the previously calculated 95th percentile volume of 0.17 acre-feet.

Per the Hawaii regulations, the water quality storage volume is calculated as follows.
WQV = P x C x A x 3630
P = 1 inch
C = 0.05 + 0.009 (% Impervious) = 0.17
A = 10.3 acres
WQV = 6,356 cubic feet
WQV = 0.146 acre-feet

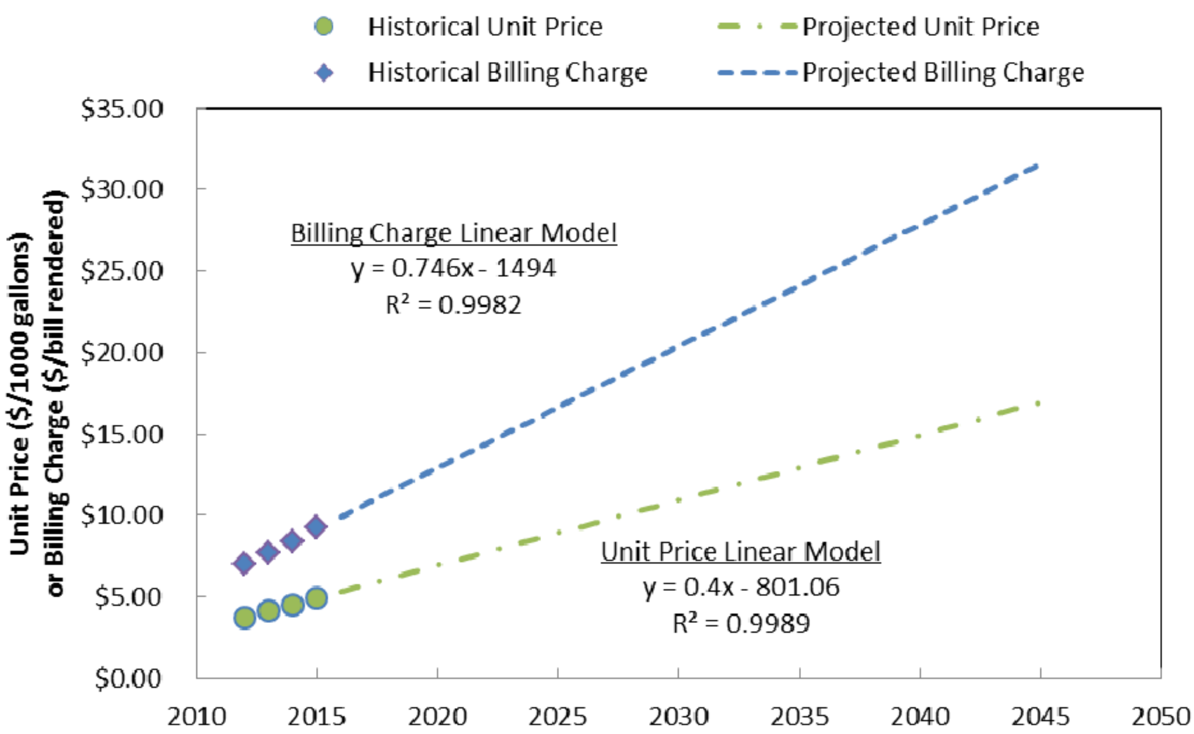
Assumptions

- Site does not drain to sump condition or roadway culvert
- Though downstream conveyance facilities are not known to be significantly under capacity, detention storage has been provided to mitigate the 10-year post-development peak flow to pre-development 10-year peak flow level.
- All offsite drainage to the project site area should be diverted around the proposed storm water BMP facility. Only flow from the project site should drain to the facility.
- It is unlikely that the pre and post-development slope and flow lengths would be exactly the same. These assumptions were made based on a lack of information regarding the proposed developed site. The calculations should eventually be updated based upon the proposed site design.

Drainage area values are the same for pre and post-developed conditions, indicated no diversion of area to or from the project site as a result of development. This assumption should be verified upon review of the proposed site design.

A.4 RAINWATER HARVESTING – FUTURE MUNICIPAL WATER COST PROJECTIONS

The following figure presents the projection of future municipal water costs based on historical data provided by Honolulu Board of Water Supply. These projected costs were used to calculate the return on investment from implementing a rainwater harvesting system.



A.5 REFERENCES

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